

## WALL LINING

### BACKGROUND INFORMATION

5           This invention relates to wall linings, especially wall linings that provide enhanced thermal efficiency.

Building walls typically comprise a rigid walling material such as brick or plasterboard covered with a wall lining such as, for example, paint and/or a sheet material like wall paper or a wallcovering.

10           There is a general desire for buildings to be energy efficient so as to reduce the costs of heating and cooling them. In the case of building walls this is normally addressed by incorporating insulating materials such as rigid foam or heat-reflective metallic sheet into the rigid element of the wall.

15           Materials commonly known as phase change materials have been used in textiles (for instance for military clothing), surgical bandages and protectors for electronic components. These materials exhibit a phase change at an operational or working temperature, in the course of which they absorb or emit heat. This gives them thermal regulating properties.

20           It has also been proposed to incorporate phase change materials into plasterboard sheet which could then be used for the rigid elements of walls. Wall boards incorporating phase-change materials have been proposed, for example, in CBS Newsletter, Fall 1997 currently available from [http://eetd.lbl.gov/newsletter/CBS\\_NL/nl16/phase.html](http://eetd.lbl.gov/newsletter/CBS_NL/nl16/phase.html) and *ASHRAE Transactions: Research*, vol. 99, part 2, paper #3724. These are rigid boards  
25           formed of gypsum into which phase change materials have been incorporated with the intention of enhancing the thermal energy storage capacity of buildings whose walls are formed of the boards.

30           Although gypsum wallboard (due to its highly porous nature) was found to make an ideal supporting medium for phase change materials, the systems that have been developed suffer from a number of problems. The preferred forms of phase change materials in such wall boards have been paraffins and fatty acids. Wall boards incorporating paraffins present flammability issues, and wall boards incorporating fatty acids (which are generally derived from meat by-products and vegetables) have been found to give off unacceptable odor levels.

Additionally, while it might be convenient to use such wall boards when constructing a new building, incorporating them into an existing room would mean replacing the existing walling of the room, which would be inconvenient, messy, and potentially so costly as to outweigh any expected energy savings.

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## DESCRIPTION OF THE INVENTION

Briefly, there is provided a flexible wall lining that includes one or more phase change materials exhibiting a phase change at a temperature in the range from 5° to 40°C. The wall lining preferably is in the form of a sheet which preferably has an adhesive layer for adhering it to a wall. Alternatively the sheet could be pasted to a wall using an additional adhesive. The adhesive layer may initially be provided with a removable backing sheet on its face opposite the body of the sheet.

The mechanism of the or each phase change is preferably endothermic with increasing temperature and exothermic with reducing temperature. At atmospheric pressure, the or each phase change material preferably has a first phase stable at a temperature below the respective phase change temperature and a second phase stable above the respective phase change temperature. The change from the first to the second phase is preferably endothermic, and the change from the second to the first phase preferably exothermic. Thus the phase change material may act as a temperature buffer about the respective phase change temperature.

Preferably the or each phase change material is in the form of particles. The size of the particles is preferably in the range from 10 to 120  $\mu\text{m}$ , or up to 300  $\mu\text{m}$ . Preferably each particle is encapsulated with an impermeable coating. This coating may be constituted by a structural material of a layer of the coating, or each particle may be individually encapsulated. The coating is preferably flexible.

The particles may be embedded in a layer of the wall coating. That is preferably a polymer layer. Alternatively the particles are adhered to an absorbent layer of the wall lining, for example by impregnating a paper or textile layer of the wall lining with the particles.

Preferably the wall lining comprises from 30 to 60% by weight or alternatively by volume of the phase change material(s). Amounts outside that range could also be used.

Conveniently the or at least one of the phase change materials is  
5 hydrated below the temperature at which it exhibits the phase change, and conveniently less hydrated above that temperature. At least one of the phase change materials may be a hydrated metal salt. Phase change materials employing other mechanisms could also be used.

If wall lining comprises two phase change materials, the temperatures at  
10 which they exhibit the said phase change may suitably differ by at least 1°C. This can help to broaden the effective buffering range of the wall lining.

The wall lining could be intended to form an exposed surface of a wall to which it is applied. In that case the wall lining could be provided with a cosmetic outer face, for example a printed outer face. Alternatively, the wall lining could  
15 be affixed to a wall and then decorated, for instance by painting or by applying a sheet material such as wall paper.

In the accompanying drawings:

Fig. 1 is a cross-section of one form of wall coating;

Fig. 2 is a cross-section of a wall to which the coating of Fig. 1 has  
20 been applied; and

Fig. 3 is a cross-section of another form of wall coating; and

The present invention now is described by way of example with reference to the drawings with like reference numerals designating like parts.

Figure 1 shows a cross-section of one form of wall coating. The wall  
25 coating of Fig. 1 is a flexible sheet having a structural or body layer 1 and an adhesive layer 2 attached to the body layer and covering one major surface of the body layer. The adhesive layer is backed by a removable backing sheet 3, which protects the adhesive layer until the coating is to be applied to a wall. The body layer 1 comprises at least one phase change material, which in this  
30 instance is provided in the form of particles 4 which are embedded in the body layer 1. The phase change material exhibits an exothermic/endothermic phase change at a working temperature. As is conventional with such so-called phase change materials, the material is such that in passing through the phase change

from below the working temperature to above the working temperature the material absorbs heat (endothermic) and vice versa. When the wall coating is applied to the wall 5 of a building (see Fig. 2) it can assist in stabilising the temperature of the building around the working temperature, and thus enhance the building's energy efficiency.

The wall coating will now be described in more detail.

The phase change material is preferably present in the wall lining in the form of particles. Figure 1 illustrates one way in which the particles may be integrated with the wall lining. In the wall lining of Fig. 1 the particles 4 are embedded in a polymer material that forms the matrix of the body layer 1. Fig. 2 illustrates another way in which the particles may be integrated with the wall lining. In the wall lining of Fig. 2, the particles have been coated on to an absorbent scrim 6 by soaking the scrim with a liquid bearing the particles, and then drying the scrim so as to leave the particles bound to the scrim. Another option would be to have the particles bound in the adhesive layer 2.

The phase change material could be incorporated in the wall lining in another way than as particles. For example, if the phase change material were in the form of a sheet then it could be laminated to the body layer 1 between the body layer and the adhesive layer 2. The phase change material could be attached to the body layer by an additional adhesive layer.

The phase change material could, for example be a hydrated metal salt such as hydrated aluminium chloride, hydrated magnesium chloride or Glauber's salt (sodium sulphate decahydrate). Alternative materials are listed in the following table.

Material	Approximate melting point (°C)
$\text{CaCl}_2 \cdot 6 \text{H}_2\text{O}$	27
$\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}$	32
$\text{MgCl}_2 \cdot 6 \text{H}_2\text{O}$	117
$\text{Na}_2\text{S}_2\text{O}_3 \cdot 5 \text{H}_2\text{O}$	48
polyethylene glycol ( $M_w > 2000$ )	45
$\text{C}_{16}\text{H}_{34}$	18
$\text{C}_{17}\text{H}_{36}$	22
$\text{C}_{18}\text{H}_{38}$	28
$\text{C}_{19}\text{H}_{40}$	32
$\text{C}_{20}\text{H}_{42}$	36

Another possible alternative is a PEG/celulose diacetate blend.

To achieve the desired thermal properties, two or more phase change materials could be used in combination.

5           The working temperature of the phase change material – that is the temperature at which its relevant phase change occurs – should suitably be in the range from 5° to 40°C. One preferred possibility is for the working temperature to be around a desired lower temperature for a building interior, so that it can release heat as the temperature falls to that level: for that purpose the

10 working temperature is suitably in the range from 8° to 14°C. Another preferred possibility is for the working temperature to be around a desired upper temperature for a building interior, so that it can absorb heat as the temperature rises to that level: for that purpose the working temperature is suitably in the range from 26° to 32°C, preferably between 28° and 30°C. Another preferred

15 possibility is for the working temperature to be around a desired ambient temperature for a building interior, so that it can moderate temperature changes in the building: for that purpose the working temperature is suitably in the range from 14° to 26°C. Broader-based effects may be achieved by using combinations of materials from one or more of these temperature ranges.

20           Many candidates for the phase change materials are hydrated materials, especially hydrated metal salts. In order to maintain such materials in a suitably

hydrated state over the lifetime of the wall lining and also during manufacture of the wall lining it is preferred that they are encapsulated in an impermeable coating. This is illustrated in figures 1 and 3, in which the particles 4 comprise a core 4b of phase change material and an impermeable outer coating 4a. The outer coating 4a seals the core 4b so that the composition of the core does not change during use. The encapsulation should be performed below the phase change material's phase change temperature since in that range its degree of hydration will be stable. The encapsulant will typically be a hydrophobic material, and it may be difficult to fully encapsulate hydrated materials with such a material. One way in which this may be achieved is by means of the micro-encapsulation technique described in US 4,675,140. That technique involves the direction of a suspension of the particles and the encapsulant on to a rotating surface. The surface centrifuges the particles surrounded by the encapsulant into air, which causes the encapsulant to cure around the particles.

Where the particles are loaded into a polymer matrix as in the coating of figure 1, the matrix itself may provide sufficient encapsulation of the particles to keep them stable during use. However, even in that embodiment it is preferred that the particles are individually encapsulated since that diminishes the possibility that the particles will deteriorate when they are loaded into the matrix during manufacture of the wall coating.

To accommodate any volume change accompanying the phase change, any encapsulant and/or matrix holding the phase change material should preferably be flexible.

The phase change material and any encapsulant should be selected to have suitable properties for safe use as a building material. For example, it should preferably be non-flammable and/or non-hazardous.

Where the phase change materials are in the form of particles, it is preferred that the particles are in the size range from 10 to 120  $\mu\text{m}$ . Larger or smaller particles could also be used. Relatively small particles are preferred as they are likely to interfere less with the handling, for example cutting, of the wall lining. The loading of the particles into the wall lining is preferably in the range from 30 to 60% by weight or alternatively by volume. To assist in achieving a relatively high loading of the particles, particles of different sizes may be used.

One preferred arrangement is for the matrix to include particles of two or more sets of sizes, each differing from the others in size by at least an order of magnitude. In this arrangement the particles of smaller sizes can occupy a considerable proportion of the volume between the larger particles. For example, there may be two sets of particles: one having a particle size of approximately 100  $\mu\text{m}$  and one having a particle size of approximately 10  $\mu\text{m}$ . The sizes of particles in each set are preferably tightly controlled to facilitate easy manufacture and to optimise filling. The particles of the largest size set preferably occupy 30 to 60% of the volume of the layer of the wall lining in which they are contained. The particles of the next smallest size preferably occupy up to 60%, and preferably 30 to 60% of the remaining volume, and so on.

The matrix of the body layer 1 is preferably a polymer material, such as a vinyl resin. The scrim 6 could be of paper or fabric.

The wall lining is preferably in the form of a flexible sheet, that can be applied to a wall in a similar way to conventional wall papers and vinyl wall linings. The finished sheet could be put in the form of a roll for shipping and storage, and unrolled for application to a wall. The outer surface of the sheet (e.g., the major surface of the body layer 1 to which the adhesive 2 is not applied, in the embodiment of Fig. 1) could have a decorative aspect. The outer surface could be pigmented by the application of a pigmented layer 7 to the surface, or the incorporation of pigment into the another layer of the sheet (e.g., layer 1). The outer surface could be embossed with a surface relief pattern. Alternatively, it could be intended that the wall lining should be decorated after having been installed. In that case it could have a plain exterior surface.

In summary, the wall linings of Figs. 1 and 3 are multilayer structures. Each embodiment comprises a layer (1,6) that forms the body of the wall lining. Phase change materials are incorporated in that layer: in one instance by being embedded in it and in the other instance by being adhered to its surface. Although it is not essential that an adhesive layer is provided, it is preferred that the wall lining comprises an adhesive layer 2 which coats one major surface of the body layer 1,6. The adhesive layer may be provided with a releasable backing layer 3 over its other major surface. One major surface of the body layer 1,6 may be provided with a decorative coating 7. If the wall lining has an

adhesive layer 2, that surface is preferably the surface of the body layer to which the adhesive is not affixed.

The wall lining could include other materials intended to enhance energy efficiency by other mechanisms. For example, it could include reflective materials such as metallic fragments or metallic sheet for heat reflection.

The adhesive layer could be omitted from the coating. The coating could be fixed to a wall by an additional adhesive applied at the time of fixing, or by another means such as tacks.

Although the coating is suitable for application to walls, in practice it could be applied to other elements such as floors or ceilings.

## EXAMPLES

### Example 1

In a plastic beaker, 118 g Reofos™ 50 flame retardant (Great Lakes Chemical Corp.; Indianapolis, Indiana) was mixed with 1 g Lankromark™ LZB320 PVC stabilizer (Akcros Chemicals Ltd.; Manchester, England) in a using a laboratory mixer. To this mixture was slowly added 50 g Evipol™ MP6852 micro-suspension PVC (EVC (UK) Ltd.; Cheshire, England); after thorough mixing, another 50 g Evipol™ MP6852 PVC was added. After thorough mixing, to the resulting low viscosity liquid was slowly added two 38 g portions (each followed by mixing) of Micronal™ DS 5001 X powdered phase change material so as to give a viscous but pourable liquid.

This liquid was poured onto an A3 sheet of 80 g/m<sup>3</sup> paper and the paper passed through a knife coater with a gap of 2 mm so as to give a thick coating. Immediately after coating the coated paper was put into an oven set at 160°C for 3 minutes. The resultant coating had a coating weight of 1,766 g/m<sup>3</sup>.

Using DSC with a heating/cooling rate of 10°C/min, the coating was found to have a melting point and a freezing point very similar to those shown by the powdered phase change material. The cured, flexible coating contained approximately 25.8% (w/w) microencapsulated wax with a melting point of ~23°C and a freezing point of ~13°C.



### Example 2

In a plastic beaker, 90 g dioctyl phthalate plasticizer (Hoechst AG; , was mixed with 1 g Lankromark™ LZB320 stabilizer, 3 g Lankroflex™ E2307 epoxidized soya bean oil (Akcros Chemicals), and 2 g Deplastol™ fatty acid polyglycol ester (Cognis Performance Chemicals) using a laboratory mixer. To this mixture was slowly added 50 g Evipol™ MP6852 PVC and, after thorough mixing, 9.32 g Sb<sub>2</sub>O<sub>3</sub> and an additional 50 g Evipol™ MP6852 PVC. After thorough mixing, to the resulting low viscosity liquid was slowly added two 40 g portions (each followed by mixing) of Rubitherm™ PX27 silica powder containing a phase change wax (Rubitherm GmbH; Hamburg, Germany) so as to give a viscous but pourable liquid.

This liquid was then poured onto an A3 sheet of 60 g/m<sup>3</sup> non-woven fabric and the coated fabric passed through a knife coater with a gap of 0.5 mm so as to give a thick coating. Immediately thereafter, the coated fabric was put into a oven set at 160°C for 3 minutes. The resultant coating had a coating weight of 450 g/m<sup>3</sup>. DSC analysis showed that the coating had a melting point and a freezing point similar to those shown by the phase change material. The cured, flexible coating contained approximately 28.0% (w/w) phase change materials with a melting point of ~9°C and a freezing point of ~0°C.

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### Example 3

Using the procedure of Example 1, 127 g Reofos™ 50 flame retardant was mixed with 1 g Lankromark™ LZB320 stabilizer. To this mixture was slowly added two 50 g charges of Evipol™ MP6852 PVC. When this had been mixed in thoroughly, a further 50 g of Evipol MP6852 was added. After thorough mixing yielded a low viscosity liquid, two separate portions of 38 g Rubitherm™ PX27 silica powder containing a phase change wax were slowly added, the second of which was accompanied by 9 g Reofos™ 50 flame retardant, and the composition thoroughly mixed so as to give a viscous but pourable liquid.

This liquid was then poured, coated, and heated as described in Examples 1 and 2 (coater gap of 1.5 mm); the resultant coating had a coating weight of 1,300 g/m<sup>3</sup>. DSC analysis showed that the coating had a melting point and a freezing point similar to those shown by the phase change material.

The cured, flexible coating contained approximately 25.0% (w/w) of the phase change material with a melting point of  $\sim 13^{\circ}\text{C}$  and a freezing point of  $\sim 1^{\circ}\text{C}$ .

#### Example 4

- 5            Similar to the procedure of Example 2, 71 g dioctyl phthalate plasticizer was mixed with 1 g Lankromark™ LZB320 PVC stabiliser, 3 g Lankroflex™ E2307 epoxidised soya bean oil, 2 g Deplastol™ fatty acid polyglycol ester, and 19 g Cereclor™ S45 chlorinated paraffin (IACC; Thailand). To this mixture was slowly added (separated by thorough mixing) two 50 g charges of Evipol™
- 10   MP6852 PVC and 12 g SBP11 solvent (Gelpe and Bate Ltd.) to give a low viscosity liquid. To this was slowly added two charges (each followed by thorough mixing) of 68 g Rubitherm™ GR30 granular diatomaceous earth containing a phase change wax (Rubitherm GmbH) to give a viscous but pourable liquid.
- 15            This liquid was then poured, coated, and heated as described previously ( $80\text{ g/m}^3$  paper, coater gap of 2.0 mm, 8 minutes of heating); the resultant coating had a coating weight of  $2100\text{ g/m}^3$ . DSC analysis showed that the coating had a melting point and a freezing point similar to those of the phase change material. The cured, flexible coating contained approximately 30.1%
- 20   (w/w) of the phase change material with a melting point of  $\sim 6^{\circ}\text{C}$  and a freezing point of  $\sim -3^{\circ}\text{C}$ .

#### Example 5

- 25            Similarly to that described in the prior examples, 64 g Reofos™ 50 flame retardant, 1 g Lankromark™ LZB320 stabiliser, 3 g Lankroflex™ E2307 epoxidized soya bean oil, 2 g Deplastol™ fatty acid polyglycol ester, and 33 g Cereclor™ S45 chlorinated paraffin were mixed. To this mixture was slowly added two 50 g charges of Evipol™ MP6852 PVC, which charges were separated by the addition of 9.32 g  $\text{Sb}_2\text{O}_3$ , 18 g Thermasorb™ 83 microencapsulated wax (Frisby Technologies Inc.; Winston Salem, North Carolina) and 12 g SBP11
- 30   solvent. This gave a low viscosity liquid to which was slowly added an additional 46 g Thermasorb™ 83 wax. Mixing was continued so as to give a viscous but pourable liquid.

This liquid was then poured, coated, and heated as described previously (80 g/m<sup>3</sup> paper, coater gap of 2.0 mm, 3 minutes of heating); the resultant coating had a coating weight of 1900 g/m<sup>3</sup>. DSC analysis showed that the coating had a melting point and a freezing point similar to those of the phase change material. The cured, flexible coating contained approximately 26.36% (w/w) of phase change material with a melting point of ~17°C and a freezing point of ~1°C.

#### Example 6

Together were mixed 71 g dioctyl phthalate plasticizer, 1 g Lankromark™ LZB320 stabilizer, 3 g Lankroflex™ E2307 epoxidized soya bean oil, 2 g Deplastol fatty acid polyglycol ester, and 33 g Cereclor™ S45 chlorinated paraffin. To this mixture was slowly added two 50 g charges of Evipol™ MP6852 PVC separated by thorough mixing and the addition of 9.32 g Sb<sub>2</sub>O<sub>3</sub>. To the resulting low viscosity liquid, 76 g Thermasorb™ 83 microencapsulated wax was slowly added and mixing was continued so as to give a viscous but pourable liquid.

This liquid was then poured, coated, and heated as described previously (80 g/m<sup>3</sup> paper, coater gap of 2.0 mm, 3 minutes of heating); the resultant coating had a coating weight of 1715 g/m<sup>3</sup>. DSC analysis showed that the coating had a melting point and a freezing point similar to those of the phase change material. The cured, flexible coating contained approximately 27.02% (w/w) of phase change material with a melting point of ~21°C and a freezing point of ~11°C.